research review

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BALLOON TECHNOLOGY: TWO MAJOR ADVANCES

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

Two significant advances in balloon technology were made recently by AFCRL scientists. Both advances were demonstrated in the launch of a single high-altitude research balloon from Holloman AFB, New Mexico.

The first advance was the successful use of a new, extremely lightweight balloon material. Balloons constructed of this material will be able to carry larger pay loads to higher altitudes than has heretofore been possible. The second advance was the demonstration of a new technique for recovering balloons intact after flight.

The new material consists of Dacron threads laminated to a thin Mylar base film. Plastic materials reinforced with a grid pattern of woven threads have been increasingly used in balloon construction during the past year or so. But the new material is distinguished by variations in the pattern of the reinforcing threads over the surface of the balloon. The weave pattern is varied in order to add strength at those points of the surface where greatest stress occurs.

The recovery technique permits, for the first time, the reuse of large research balloons. Balloons are ordinarily and necessarily expendable items. The termination of a flight requires destruction of the balloon. Each balloon costs between $2,000 and $30,000. Thus, the recovery-and-reuse technique will provide a considerable savings to users of research balloons. AFCRL alone, during the first 5 months of 1965, launched 72 large research balloons.

The particular balloon flight used to test the two techniques is considered by AFCRL scientists to be one of the most significant balloon experiments of the past decade. The balloon was launched from AFCRL's permanent balloon-launch station at Holloman AFB on 21 May. It was recovered--fully deflated and literally wrapped in a protective Nylon package--in mountainous terrain near Roswell, New Mexico.

Both contributions to balloon technology were made by AFCRL scientists. Arthur Korn developed a special loom, designated the "Flying Thread Loom," which makes it possible to continuously vary the angle of the woof with respect to the web, and to vary the thread density to obtain differing strengths over the surface of the material. With the Flying Thread Loom, it is possible to tailor

balloon material to match the pay-load and altitude mission requirements of a particular balloon, thus achieving an optimum strength-weight ratio. The new material will make possible, for the first time, balloon flights to altitudes as high as 180,000 feet, a substantial increase over the present 150,000-foot altitude limit.

The balloon-recovery technique developed by James Payne is both simple and ingenious. It employs two parachutes in tandem. The lower parachute assembly is conventional and carries the pay load. The upper parachute assembly is attached to the top of the lower parachute. This assembly, during flight, is located between the inflated balloon and the lower parachute-pay-load assembly.

The first step in the recovery process is the controlled deflation of the balloon, and the deployment of the upper and lower parachutes. The upper parachute has a sizeable opening in its center through which the neck of the balloon is fitted. Thus, when the upper parachute opens, it rides up the neck of the balloon as the balloon deflates. The center hole of the parachute through which the balloon passes, however, is not an open one. Attached to the opening is a cylindrical Nylon sleeve. As the parachute moves up along the balloon, the sleeve envelops the deflated balloon material. When the deflated balloon is thus ensleeved, the upper parachute carrying the wrapped and protected balloon material is separated from the lower parachute carrying the pay-load package.

So well did the technique work on the 21 May balloon test, that the same balloon was scheduled for an additional flight. ★

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JACOB SEIDEN
Editor

BALLOON TECHNOLOGY: TWO MAJOR ADVANCES
Aerospace Instrumentation Laboratory, AFCRL 1

ECHOLOCATION BY BEAT-NOTES
Col. Herman I. Chinn..... 3

CLARITY CLEARLY DEFINED
Optical Physics Laboratory, AFCRL 4

SOLAR ROTATION: A NEW THEORY
Space Physics Laboratory, AFCRL..... 5

THE DEFORMATION BEHAVIOR OF BICRYSTALS OF B. C. C. METALS
Rollin E. Hook..... 6

A LASER – BEAM SCHLIEREN SYSTEM
1st Lt Richard T. Goddard and 1st Lt Arthur J. Wennerstrom..... 7

NUCLEAR-STRUCTURE STUDIES BY MEANS OF BETA-GAMMA ANGULAR CORRELATIONS
Dr. Joe C. Manthuruthil..... 10

NEW INSTRUMENTS FOR AIRBORNE GEOLOGICAL SURVEYS
Captain Donald W. Glick..... 17

A HIGH-ENERGY MOLECULAR-BEAM ACCELERATOR
Dr. Amos G. Horney..... 18

ON AN ATMOSPHERIC DOPPLER SHIFT AND ITS RELATION TO THE GRAVITATIONAL FREQUENCY SHIFT
Dr. Bruno J. Manz..... 20

HIGH-TEMPERATURE SILICA GLASS
1st Lt Frank E. Wagstaff and Captain Kenneth J. Richards 22

MOMENTUM INTEGRAL SOLUTIONS FOR MAGNETOHYDRODYNAMIC BOUNDARY LAYERS
Captain Rodney D. Hugelman 23

SYMMETRIES IN ELEMENTARY-PARTICLE PHYSICS...
Dr. C. P. Poirier..... 26

NUMERICAL TREATMENT OF BOUNDARY-VALUE PROBLEMS
Paul J. Nikolai..... 28

LATERAL INSTABILITY BY PARAMETRIC EXCITATION
Major B. R. Agins..... 30

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OAR 63-1

ECHOLOCATION BY BEAT-NOTES

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Despite the repulsion and fear which it excites in a sizable portion of the population, the bat has always been a favorite of the biologist. Its amazing agility, its speed and its skill as a nocturnal predator have long stimulated the admiration and curiosity of the observer. Bats can capture a mosquito every 10 seconds for periods up to 30 minutes in duration. They can fly through wire barriers only a wingspread apart, and in pitch dark. They can change direction at full speed within a few inches. By simple, yet classic, experiments, the Italian naturalist, Spallanzani, established in 1794 that the bat depends almost entirely upon his ears for orientation. Later, this ability was shown to depend upon a highly developed sense of echolocation roughly comparable to that of radar. The bat emits high-intensity bursts of sounds in the larynx. A typical pulse is 1 to 4 milliseconds, which is repeated at a variable rate. This pulse-repetition rate may be less than 10 per second while the bat is cruising, but may rise to more than 100 per second during its attack. From an analysis of the returning echo, the bat can make the appropriate maneuver.

This analogy with radar, however, is oversimplified and misleading. One mystifying characteristic is the bat's extraordinary resistance to "jamming." Swarms of bats can hunt simultaneously with the production of a multiplicity of echoes without apparently interfering with each other's orientation. Artificial sound fields with the same frequency bands as emitted by bats have been experimentally created, having a noise intensity 30,000 times that of the bat echo. Nevertheless, the bat can fly in these intense fields with no evident impairment. The bat can fly in heavy rain or among the foliage of trees, and yet unerringly capture the mosquito or the moth it pursues. Puzzling, too, is the accuracy of the bat's mechanism at very short ranges. Here, the echo front returns before the bat has finished emitting his signal. The strong emission pulses would be expected to mask the much weaker returning echo. Instead, it is in this range that the accuracy of the echolocation mechanism seems most striking.

Recently, Dr. J. D. Pye of the University of London has suggested a theory which seeems to reconcile these paradoxical observations. Supported by AFOSR, Dr. Pye has been studying diverse species of bats in an attempt to derive a unifying theory. Pye believes that the overlap of probing pulses and returning echoes is actually a necessary part of the detection mechanism. This is a rather startling suggestion, for the overlap has been considered heretofore as a masking effect which would impair reception and make echolocation more difficult. According to Pye's concept, the bat does not attend to the echo itself, but rather to beats between the echo and the original call. These beats would be heard as separate notes, or beat-notes.

One species of bats emits a frequency-modulated pulse. Since the rate of frequency change is constant, the difference in frequency is constant and proportional to the echo delay. Thus, the frequency of the beat-note will be characteristic of the echo delay which, in turn, will indicate the range of the target. Each echo from multiple targets would produce an independent beat-note which can be discriminated by the ear. Since these notes will be slightly different in each ear, the bat will also receive directional information.

A second species of bats emits pulses of constant frequency. Here, the beat theory provides a sensitive method for the detection of Doppler shifts. The Doppler shift depends upon the relative velocity of the bat to the obstacle. The greater the relative velocity, the higher the Doppler factor. The echo frequency is the product of the emitted frequency and the Doppler factor. Thus, a bat approaching an obstacle at 10 meters/second (approximately 22.5 miles/hour) will have a Doppler factor of 1.0625. If the bat is

Col. Chinn was on active duty at AFOSR when he wrote this article.

emitting a pulse of 100 kilocycles/second frequency, the returning echo will have a frequency of 106.25 kilocycles/second (100 kc x 1.0625). This would give a beat rate of 6.25 kilocycles per second. For this method to work, the ears of the bat must be highly directional. The ears of this species of bat make quick and independent searching movements. In addition, there are extremely rapid flickering movements which impose additional Doppler shifts on the echoes which provide directional sensitivity. Pye's theory thus appears to account satisfactorily for echolocations from two diverse species employing different emission pulses.

Pye has developed a relatively crude apparatus to test the ability of the human ear to detect obstacles by such a beat-note echolocation. Pulses are generated, and the beat-notes produced with echoes are heard through earphones. The implications of such devices as an aid to the blind or for military applications are obvious. ★

CLARITY CLEARLY DEFINED

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How clear is a clear day? The question is meaningless unless there is a standard reference of "clarity." And even then precision is compromised unless the standard reference defines clarity as a function of wave length and altitude.

This problem has been effectively treated in a new "Atmospheric Attenuation Model" developed by Louis Elterman of AFCRL. This model represents an extension of existing international standards incorporated in the International Visibility Code. It consists of tables of atmospheric attenuation coefficients for 22 wave lengths of light, ranging from the near-ultraviolet through the near-infrared. With these tables, it is possible to calculate what percentage of light will be transmitted over a given path through the atmosphere. This sort of calculation is essential in the design of Air Force equipments which involve the interaction of light with the atmosphere. Photoreconnaissance and laser radar and communications equipments are the most obvious of these.

The atmosphere's optical properties vary widely depending on size, shape, and composition of suspended particles. The pollen, bacteria, water droplets, smoke, and dust (including meteoritic particles) of which atmospheric aerosols are comprised have differing scattering and absorption properties at different wave lengths.

Ozone is another important contribution to the atmosphere's optical properties. It attenuates light by absorption, especially in the ultraviolet region. Other air molecules scatter light in all directions; this has the effect of diminishing the intensity along a given path. Molecular (frequently called Rayleigh) scattering, in contrast to aerosol scattering, decreases in a fairly well-known (and thus easily calculable) manner from sea level to extreme altitudes.

Using atmospheric densities taken from the latest U.S. Standard Atmosphere (another important model to which AFCRL scientists have made major contributions), and experimental values for average aerosol and ozone concentrations taken from a number of sources, Elterman calculated attenuation coefficients at 1-km intervals for altitudes up to 50 km, where all atmospheric attenuation becomes negligible. He also proposed several formulas to facilitate calculations of atmospheric attenuation along various paths. These include: horizontal paths at any altitude; vertical paths from any altitude to any other altitude; and slant paths in any direction from any altitude to any other and to space.

The usefulness of Elterman's Atmospheric Attenuation Model is indicated by the hundreds of inquiries and requests which he has received from researchers both in this country and abroad, including the U.S.S.R. The tables in the model will be reproduced in the next edition of AFCRL's Handbook of Geophysics and Space Environment. ★

SOLAR ROTATION: A New Theory

SPACE PHYSICS LABORATORY, AFCRL

What we see when we look at the sun is not a solid surface, but a dense turbulent plasma known as the photosphere. Of the unknown and puzzling features of the sun, one of the most puzzling is that the photosphere of the sun rotates faster at the equator than at the poles--a rotation rate of about 25 days at the solar equator compared to a rate of about 30 days near the poles.

A number of theories have been advanced to explain this difference in rotation rates, but none enjoys widespread acceptance. In a paper appearing in Pure and Applied Geophysics, Dr. Fred Ward of AFCRL sets forth a new and intellectually satisfying theory. This writing has been awarded AFCRL's Marcus D. O'Day Memorial Award as the best AFCRL paper published in a reputable scientific journal during 1964.

What has bothered astronomers most in the past is that the faster rotation at the solar equator seems to contradict basic physical principles. To maintain a faster rotation at the sun's equator against the frictional forces which tend to slow it down requires the transfer of angular momentum from a region of lower angular momentum to one of high angular momentum. This is an uphill process, roughly analogous to boiling water with an ice cube. But this could be done if there were order in the system permitting only the fastest molecules in the ice to be transferred to the water.

The order in the system postulated by Ward comes in the form of Rossby waves. Rossby waves are believed to be the momentum source of the jet stream in the earth's atmosphere. Rossby waves appear from above like saw-tooth-shaped patterns which transfer angular momentum from one region of a rotating body to another region, thus causing the flow in that region to be faster than the surrounding regions. Rossby waves are believed to be the result of the earth's rotation and the temperature difference between the equator and pole.

That Rossby waves could be used to explain the sun's equatorial acceleration was first suggested to Ward by the results of the dishpan experiments of Prof. Dave Fultz of the University of Chicago and Prof. Raymond Hide of MIT which were supported by AFCRL contracts. Dishpan experiments are used to simulate the effect of planetary or solar rotation on the circulation patterns of their atmospheres. In these experiments, two cylinders, one inside the other, are commonly used. A liquid is placed in the space between the two cylinders which are rotated. If a temperature difference between the liquid at the center of the cylinder (corresponding to the pole) and at the edge (corresponding to the equator) is maintained, and the cylinder is rotated fast enough, Rossby waves appear in the liquid. However, this result only indicates the possibility that such a process might occur on the sun.

To support his hypothesis with more direct evidence, Ward examined a large body of data on sunspot movements. Sunspots are subject to two kinds of motion. Since they are imbedded in the sun, they rotate with it. A second type of sunspot movement, called "proper motion," refers to the motion of the sunspots independent of the sun's rotation, and is analogous to the movement of storm centers across the earth's surface. It is this type of sunspot motion that Ward used to support his hypothesis.

The "proper motion" of sunspots has both east-west and north-south components. Ward found that, on the average, sunspots moving towards the equator had a higher easterly velocity (same direction as the solar rotation). This indicates that momentum is being transferred from the polar regions to the equatorial regions, and thus lends strong support to Ward's theory on solar rotation.★

The Deformation Behavior Of Bicrystals Of B.C.C. Metals

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There is no doubt but that grain boundaries play a significant role in the strength and ductibility of polycrystalline body-centered cubic metals such as iron, tungsten, molybdenum, etc. The interstitial impurity elements such as carbon and nitrogen which significantly affect the mechanical properties of these metals seem to exert considerable influence as a result of grain boundary-interstitial element interaction. A logical approach towards more fully understanding the mutual interaction between crystals and the role of grain boundaries is to undertake an examination of the deformation behavior of bicrystals of the type shown in Fig. 1.

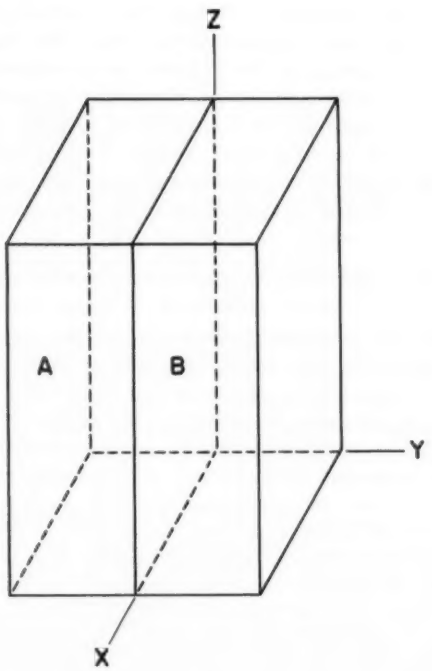

FIG. 1 BICRYSTAL CONFIGURATION

Here if the individual crystals are of known and controlled orientation, the results are amenable to a more meaningful analysis than in studies of polycrystalline specimens where the deformation is more complicated. Although bicrystal deformation has been studied in face-centered cubic metals such as aluminum, as yet no studies have been undertaken on bicrystals of a body-centered cubic metal.

From earlier work on aluminum (1) evolved the concept of "macroscopic compatibility" as a condition necessary for the macroscopic deformation of a bicrystal, i.e., the two crystals are required to deform identically with respect to the strain components which control the deformation of the grain boundary plane. If the orientations of the component crystals are such that this condition is not initially satisfied, it leads to the operation of additional slip systems (systems other than those which would operate in the individual crystals if deformed separately) near the grain boundary which affects the work hardening of the bicrystal.

Since the number of different types of bicrystals is practically unlimited, it is useful to consider only a few special cases:

1. A symmetrical bicrystal is one in which the component crystals A and B are mirror images of each other across the XZ boundary plane; this type of bicrystal is compatible provided it is isoaxial.

2. A pseudosymmetrical bicrystal is one resulting from the combination of two symmetry operations, one with respect to the grain boundary and the other with respect to the slip plane. In this case the primary slip systems are symmetrical with respect to the grain boundary, but the crystal lattices are not symmetrical. Therefore, although this bicrystal is compatible with respect to the primary slip systems, it is not compatible with respect to secondary slip systems.

3. A pseudoidentical bicrystal is one in which both component crystals have the same primary slip plane and slip direction in common, i.e., the primary slip system is continuous across the grain boundary. This type of bicrystal is compatible.

Of importance in regard to the stress-strain behavior of bicrystals are the relative orientations of the stress axis and crystal orientations. These determine the values of the resolved shear stresses on the primary and secondary slip systems. For all isoaxial cases, the component pair of single crystals will each have the same stress-strain curves; but for nonisoaxial cases, the component pairs of single crystals will each have completely different stress-strain curves. The shear stress on secondary slip systems is very important because the secondary system will become operative as soon as the stress is increased from that due to the applied load to that value necessary to activate slip.

A microscopically compatible bicrystal can still be stronger than its component single crystals due to microscopic incompatibilities such as a lack of one-to-one correspondence of slip planes at the grain boundary. The superimposed shear of one crystal on another due to dislocation pile-ups at the grain boundary could activate secondary slip even if the bicrystal is macroscopically compatible and designed to deform only on the primary slip systems. This secondary slip cannot be produced in a pseudoidentical bicrystal. It can exist in a symmetrical bicrystal, but it will not be important since even the secondary slip systems are symmetrical. For a pseudosymmetrical bicrystal, however, secondary slip destroys its compatibility since this type of bicrystal is not compatible with respect to its secondary slip systems. In this way a pseudosymmetrical bicrystal could be appreciably stronger than its component single crystal.

In order to examine these ideas experimentally, a study is being made of the deformation in bicrystals of controlled orientation in an Fe-3% Si alloy, which was chosen for this study for the following reasons:

(a) Large single crystals of this alloy can be grown from the melt, and bicrystals can also be prepared to a limited extent by seeding.

(b) Of all the b.c.c. metals or alloys, Fe-3% Si seems comparatively rather well behaved since crystals oriented for single slip (<111>, {011} type) only show single slip.

(c) Slip can be studied quite well using proven etch-pitting techniques.

(d) This material lends itself quite well to examination by electron-transmission microscopy.

Large single crystals of controlled orientation (1/2" x 1/2" x 3") are being grown from the melt in hydrogen. Bicrystals are produced by diffusion bonding of two single crystals together (of the previously mentioned types) as well as others. The slip occurring at various degrees of deformation is being examined by etch-pitting techniques with specific samples being selected for examination by electron-transmission microscopy. So far it has been verified that the slip occurring in macroscopically compatible bicrystals is not microscopically compatible.

When complete, this study will increase our understanding and knowledge concerning the role of grain boundaries in the deformation of body-centered cubic metals, an extremely important class of AF materials. ★

REFERENCE

(1) Hauser, J. J. and B. Chalmers, "The Plastic Deformation of Bicrystals of F.C.C. Metals," Acta Met., 9, Sept. 1961, pp. 802-818.

A Laser-Beam Schlieren System

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The schlieren system of the Fluid Dynamics Facilities Laboratory has recently been revised to incorporate both a continuous and a pulsed laser for the system light source. A schlieren system is an instrument for the visualization of aerodynamic flow fields. At ARL, such a system is employed in conjunction with the Laboratory's 20-inch Mach-14 hypersonic wind tunnel to aid scientists in understanding complex aerodynamic phenomena. In describing this remarkable instrumentation tool, a discussion of basic

schlieren systems, schlieren sensitivity, and the present laser system will be given.

A schlieren system functions basically along the following lines. Lenses cause light emitting from a small but intense source to be formed into a parallel beam which is passed through a wind-tunnel test section. The shock waves and boundary-layer interactions associated with a model submerged in the hypersonic gas stream result in density gradients which cause variations in the index of refraction of the gas. The light which has passed through the test section is refocused to a point where a knife edge blocks a portion of the beam. The light which is not blocked by the knife edge is passed to a viewing screen where an image of the test object is formed. Those rays which were deflected toward the knife edge cause dark portions to appear in those parts of the image where the deflection took place. Similarly, those rays deflected away from the knife edge cause bright regions to appear. The light source and optical arrangement of any particular schlieren system determine the sensitivity of that system.

The sensitivity of a schlieren system may be defined as the ratio of light-intensity variation to background intensity, for a given disturbance. In a particular schlieren system, a given disturbance will cause a particular beam deflection at the knife edge. Therefore, the two parameters which may be varied to significantly change the sensitivity of a given schlieren system are the size of the spot at the knife edge, and the total light intensity. As the size of the spot of light at the knife edge decreases, a fixed value of beam deflection will represent an increasingly greater proportion of light either cut off or totally passed by the knife edge. Therein lies one of the greatest virtues of the laser for schlieren use. A conventional light source has a limiting minimum dimension to which it can be focused and still provide enough light for photographic purposes. A laser is inherently much better collimated than any other light source and produces light which can be focused to a spot size near the diffraction limit while still passing a sufficient quantity to take excellent photographs. A further advantage of the pulsed ruby laser is that exposures of about 1/25 microsecond duration can be made. This is sufficiently fast to "freeze" any transient flow condition anticipated.

This laboratory's laser-light source was developed and constructed by Aircraft Armaments, Inc., under Contract AF 33(615)-1914. The system has a usable light source with an area 1/100 of that of the original source. At present, the system is still undergoing evaluation at ARL, but several initial observations can be made. First, the quality required for the schlieren optical elements cannot be too highly stressed; the laser sources were installed on an existing schlieren system which had excellent optics when used with a conventional source. However, the full potential sensitivity of the laser system cannot yet be achieved because these original optics cannot reproduce a 0.001-inch source diameter to smaller than 0.004 inch. All optical elements must be of diffraction limited quality before the true potential can be realized. The system sensitivity with the laser, however, is now approximately four times better than could be realized with the original light source and, with improved optics, this can be increased to one order of magnitude. A second problem of no small significance is caused by vibrations in the schlieren environment. These vibrations cause slight movements of the knife edge. The movements make it difficult to obtain pulsed-ruby photographs. However, by placing the knife edge in the vertical position, some of the vibration effect is removed. Various other means to cope with this problem are now under study.

The photograph in Figure 1 shows a two-dimensional, double-wedge model used to study the viscous region behind the shock intersection. The tunnel conditions for this run were a Mach number of 14.0, and a stagnation pressure of 1400 psi. The picture was obtained using the pulsed ruby laser and a vertical knife edge. Figure 2 is a schlieren photograph of the same model under identical tunnel conditions with a conventional mercury light source.

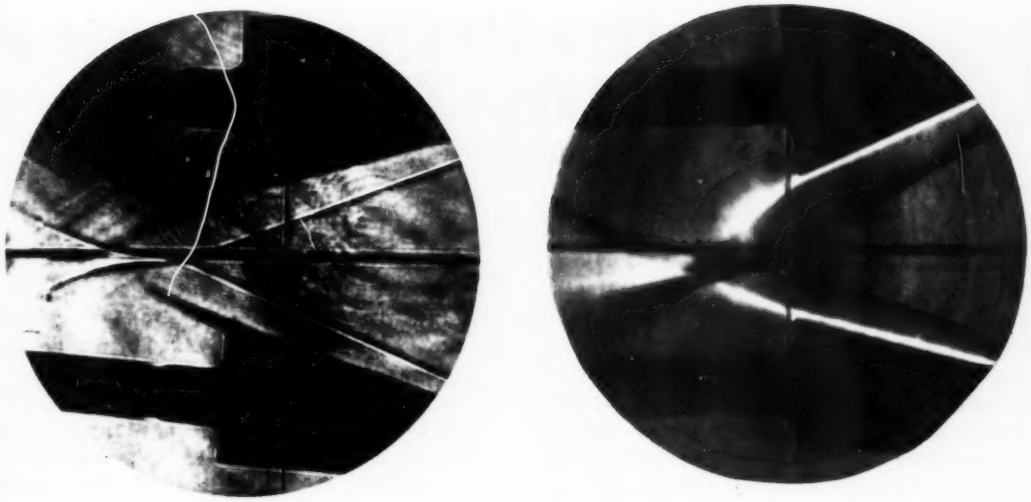

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Figure 1. Schlieren Photograph Taken with Pulsed Ruby Laser Light Source.

Figure 2. Schlieren Photograph Taken with Conventional Mercury Light Source

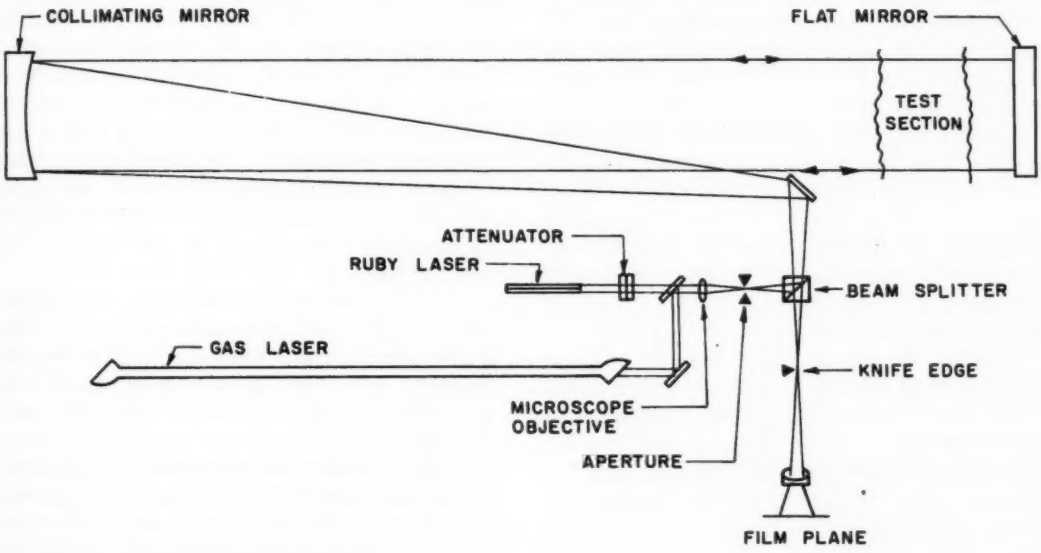

Figure 3. Laser Schlieren Schematic

It is highly significant that, although the camera shutter speed was 1/50 second in each case, the effective time exposure for the first photograph was 40 nanoseconds, and for the second 20,000,000 nanoseconds. The increased definition in Figure 1 is due both to higher sensitivity and shorter exposure time.

It is anticipated that, when the system is further refined to eliminate current difficulties, the use of this powerful research tool will be extended deep into the hypersonic regime and may provide new insight into hypersonic phenomena now under study.

Nuclear-Structure Studies by Means of Beta-Gamma Angular Correlations

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Nuclear-structure studies of nuclei (with atomic number $A > 100$) are generally done by means of radioactive decay. The majority of the nuclei decay through beta emission. The study of these nuclei had been, until about 1958, primarily concerned with establishing a theory for the beta-decay interaction. These studies resulted in the V-A theory which has had considerable success in explaining the various observed properties of the beta-decay process such as lifetime (usually expressed as the comparative half life or ft - values), spectrum shapes, and various angular correlations. (The V-A notation refers to the fact that, of the five general types of tensor operators which can appear in the interaction, only the vector and axial vector operators contribute. The minus sign denotes the fact that the coupling constants for these operators are of opposite sign). This theory suffers, however, from the fact that it is essentially phenomenological in nature since no way is known to include explicitly the effects of nuclear structure on the decay process; these effects appear in the theory in the form of matrix elements of operators between initial and final nuclear states. Since there is no reliable way at present of computing nuclear wave functions, these matrix elements are left as parameters in the theory to be determined empirically. The above-mentioned properties are, in the general case, independent of the matrix elements involved in the transition and so are adequately described without information about any nuclear-structure effects.

The various observables of beta-decaying nuclei are, in the majority of cases, adequately described by the V-A theory without accounting for differences in nuclear structure. There are, however, several examples of deviations from normal properties of these transitions. These differences are especially observed in comparative halflives which are several orders of magnitude too large, and deviations from the usual dependence of spectrum shapes and angular correlations of the beta energy. If the V-A theory is to be accepted, these deviations must be assumed to result from nuclear-structure effects which enter the theory through the nuclear matrix elements.

After a study of the existing evidence, Kontani (1) and others (2) suggested that, assuming the results of the V-A theory, experimental measurements of the various observables in these cases might be used to obtain numerical values for the contributing matrix elements. In this reference, they provided theoretical expressions applicable to these transitions which could be compared to experimental results. If such measurements can be made, and a sufficient body of data on the nuclear matrix elements can be collected, then the ultimate hope is that this data will provide a partial basis for a more general understanding of nuclear structure. A more immediate goal is the testing of qualitative predictions of presently used nuclear models.

The possibility of obtaining numerical values for nuclear matrix elements has provided the motivation for a considerable amount of research on these anomalous transitions. This research has been primarily concentrated on a group of first forbidden nonunique transitions (ΔI [change in nuclear spin] = 0, 1 and change in parity) which show especially large deviations from the normal. This group contains the nuclides Ga^{72}, Sb^{124}, Eu^{152}, Eu^{154}, Re^{188}, Re^{186}, Tm^{170}, Rb^{86}, Rb^{84} and others. These are examples of unstable nuclei which decay by beta emission to the first excited states of the respective daughter nuclei which then de-excite to stable ground states by emission of gamma radiation (see Fig. 1). One observable that can be measured is the beta-gamma directional correlation. The

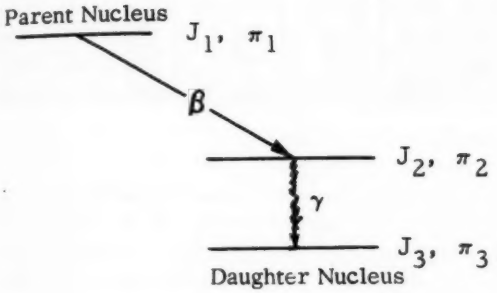


Fig 1

The J's and π's denote spin and parity of the nuclear state

object of the measurement is to determine, as a function of the beta-ray energy, the dependence of the observed gamma intensity on the angle between the directions of emission of the two radiations. The results of these measurements are then used, with the proper theoretical expressions and other measured observables, to obtain information concerning the effects of nuclear structure on the decay process.

So far, it has been possible only to test the qualitative predictions of nuclear models. In order to test the quantitative predictions of various nuclear models, a large number of nuclei have to be measured accurately before one can know their systematics and thus apply different models. It should be stressed that, whatever the example, the measurements are extremely difficult both in the technical executions and the interpretation of the results. However, more and more nuclei are being studied and theoretical calculations (3, 4) are being done at the present time. These calculations have resulted in the understanding of some nuclides on the basis of either the Shell model or the Collective model. It is felt that more accurate measurements and further theoretical calculations can provide the much-needed information on nuclear structure. ★

REFERENCES

(1) Kontani, T., Physical Rev., 114, 795, 1959.

(2) Morita, M. and R. S. Morita, Physical Review, 109, 2048, 1958.

(3) Bogdan, D., Nuclear Physics, 48, 273, 1963.

(4) Wahlbom, S., Nuclear Physics, 58, 209, 1964.

SCIENTIFIC notes

New JAFNA Radar Facility at Wallops Island: AFCRL has undertaken the operation of a $20-million radar facility located at Wallops Island, Virginia, where NASA maintains a large rocket and missile launch complex. This is under the Joint Air Force/NASA (JAFNA) Program. The radar facility was set up several years ago by Lincoln Laboratory (MIT) and has been used by Lincoln Laboratory to study missile reentry problems, a program now completed. In July, the AFCRL Meteorology Laboratory began to use the facility to study radar echoes in the clear atmosphere. More specifically, investigations are being made on the feasibility of using radar signals for detecting regions of clear air turbulence. Operations are now in full swing involving three large radars, two with antennas of 60 feet, and one of 34 feet. These radars operate in the X, S, and UHF bands. (Meteorology Laboratory, AFCRL)

Guide for Visualizing Crystal Symmetries: It is difficult for a crystallographer to visualize the spatial arrangement of atoms in a particular lattice structure. To determine these spatial arrangements, the crystallographer usually must go to several reference documents and make many calculations on permissible arrangements. This process of arriving at spatial arrangements will be greatly simplified as the result of a unique reference chart prepared by Stanley Dickinson of AFCRL. The chart covers the 230 mathematically possible geometries--or space groups--of crystal lattices. Prior to its publication, Dickinson tested its usefulness by providing the chart in preliminary form to Harvard to be used in classroom instruction. Preparation in final form was guided by this classroom experience. The chart and an associated guide book for its interpretation will be made available to interested scientific activities. (Solid State Sciences Laboratory, AFCRL) ★

PROFILES

1st/Lt Arthur J. Wennerstrom is a research scientist with the Fluid Dynamics Facilities Laboratory, ARL. He is coauthor of the article, "A Laser-Beam Schlieren System," which appears in this issue of the Review. Lt Wennerstrom has a B.S.M.E. from Duke University (1956), and an M.S. in Aeronautical Engineering from MIT (1958). He has also completed work for his Ph. D. at the Swiss Federal Institute of Technology in Zurich, Switzerland. At ARL, Lt Wennerstrom is currently doing research related to supersonic axial compressors and blunt-trailing-edge axial compressor blading.

Dr. Joe C. Manthuruthil, a research scientist with the General Physics Research Laboratory, ARL, entered the United States from India in September 1958. From 1962-1964, he was a research assistant at Indiana University. He has a B. S. in Physics and Mathematics from Poona University, India (1956), an M. S. in Physics from the University of Detroit (1960), and a Ph. D. in Physics from Indiana University (1964). Dr. Manthuruthil is a member of the American Physical Society. In this Review, he writes on "Nuclear-Structure Studies by Means of Beta-Gamma Angular Correlations."

1st/Lt Richard T. Goddard was assigned as a research scientist to the Fluid Dynamics Facilities Laboratory, ARL, in October 1962. This Laboratory has the responsibility to accomplish, promote and sponsor research in the general area of fluid dynamics. Lt Goddard was graduated from the U.S. Air Force Academy in 1961, at which time he received a B.S. in Engineering Sciences. In 1962, he received an M. S. in Aeronautical Engineering from the University of Southern California. Lt Goddard is the coauthor of the article, "A Laser-Beam Schlieren System," which appears in this issue of the Review.

Dr. Frederick W. Ward, Jr., is chief of the Forecasting Techniques Section, Space Physics Laboratory, AFCRL. He has a B. S., M. S. and Ph. D. in Meteorology, all earned at M.I.T. in 1952, 1955, and 1957, respectively. As revealed by his studies, it appears that the sun's atmosphere has a wind circulation which has many of the characteristics of the circulation of the upper troposphere in the earth's atmosphere. This would provide the answer to the long-standing question of the maintenance of the sun's equatorial acceleration, a problem of fundamental importance in solar physics. Dr. Ward is now seeking to obtain direct confirmation of these results. This issue of the Review includes an article, "Solar Rotation: A New Theory," which reflects some of Dr. Ward's work.

Dr. Hermann Poeverlein received the degrees of Diploma Physicist (1936) and Doctor of Natural Sciences (1942), both from the Technische Hochschule Muenchen, Germany. He is presently a research physicist with the Ionospheric Properties Branch, Upper Atmosphere Physics Laboratory, AFCRL. Dr. Poeverlein is currently engaged in theoretical work in the fields of VLF and ELF propagation, wave propagation in stratified media, and waves in plasmas. He has a number of publications to his credit. Implications of a study recently carried out by Dr. Poeverlein are reported in the article, "Earth Currents and Magnetic Field Variations," which appeared in the July 1965 issue of the Review.

Captain Rodney D. Hugelman is a research mathematician assigned to the Applied Mathematics Research Laboratory, ARL. He has a B. S. in Aero Engineering (1956), and an M. S. in Aero Engineering (1958), both from Oregon State University. He has done further work at Oklahoma State University (under the AFIT program) toward a Ph. D. in Mechanical Engineering. At ARL, Captain Hugelman is presently investigating some momentum integral methods for the solution of magnetohydrodynamic boundary-layer problems. This work is reflected in his article, "Momentum Integral Solutions for Magnetohydrodynamic Boundary Layers," which appears in this issue of the Review.

Dr. C. P. Poirier has been a research physicist with ARL since 1964. In his current work at the General Physics Research Laboratory, he is analyzing the reactions produced by 960 Mev/c π^+ on protons using film obtained from the 20" hydrogen bubble chamber at Brookhaven. This research is in collaboration with scientists at Ohio and St. Louis Universities. Dr. Poirier has a B. S. from the University of Detroit (1955), as well as an M. S. (1962), and a Ph. D. (1964), both from Indiana University. He has several publications to his credit. In this issue of the Review, he discusses "Symmetries in Elementary-Particle Physics."

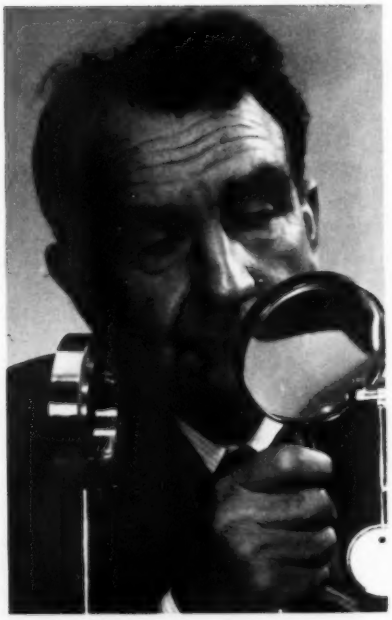
Mr. Charles K. Wilk, a research electronic engineer with the Aerospace Instrumentation Laboratory, AFCRL, is currently involved with the development of meteorological parameter – measurement systems. He joined AFCRL in 1964. Prior to that, until 1962, he was engaged in the design and development of solid-state data-processing systems at the Addressograph-Multigraph Corp., Cleveland, Ohio. Mr. Wilk has a B. E. E. degree from Fenn College, Cleveland, Ohio (1958), and an M. S. in Electrical Engineering from Pennsylvania University (1964). He is contract monitor for the "Radar Data Integrator" described in the July 1965 issue of the Review.

Mr. Paul J. Nikolai has been a research mathematician with the Applied Mathematics Research Laboratory, ARL, since 1960. In his current research, he is conducting studies in numerical analysis, with emphasis on ordinary and partial differential equations. He is also programming special problems for the IBM 7094 computer, and is making a study of extremal properties of special matrix functions. Mr. Nikolai has a B. A. in Mathematics from the College of St. Thomas (1953), and an M. Sc. in Mathematics from Ohio State University (1955). He has several publications to his credit. In this issue of the Review, he writes on "Numerical Treatment of Boundary – Value Problems."

PROFILES

Captain Kenneth J. Richards, research scientist with the Metallurgy and Ceramics Research Laboratory, ARL, is coauthor of the article, "High-Temperature Silica Glass," which appears in this issue of the Review. He has a B. S. in Chemical Engineering from the University of Utah (1956), and a Ph. D. in Metallurgy from the same university (1962). Captain Richards' current research effort is directed toward an investigation of defect structures of nonmetallics. This investigation involves the use of mass-spectrographic, radio-tracer, and electron-probe techniques to determine the nature of defects in nonmetallic materials by the study of diffusion processes.

1st/Lt Frank E. Wagstaff, a research scientist with the Metallurgy and Ceramics Research Laboratory, ARL, is currently doing research on defect structures of nonmetallics. His effort is part of a program employing mass-spectrographic, radio-tracer and electron-probe techniques to investigate the nature of defects in nonmetallic materials by the study of diffusion processes. Lt Wagstaff is coauthor of "High-Temperature Silica Glass" which appears in this issue of the Review. He received his B. S. in Ceramic Engineering from the University of Washington (1959), and his Ph. D. in Ceramic Engineering from the University of Utah (1962). He has several publications to his credit.



Dr. Heinz Fischer came to AFCRL in 1948 after working for three years as a consultant physicist at Wright-Patterson AFB, Ohio. He received his M. A. in Electrical Engineering (1930) and his Ph. D. in Physics (1935), both from the Technical University of Karlsruhe, Germany. In 1938, he received his degree of Dr. Habil in Physics from the Technical University of Darmstadt, where he was a lecturer and later chief engineer of the Physics Department. He is now senior scientist, Optical Physics Laboratory, AFCRL, and is currently engaged in research directed toward the analysis of ultradense high-temperature plasma. Dr. Fischer has a great number of publications to his credit, as well as several patents and awards, and is a member of numerous professional societies. The article, "Nanosecond Light Pulses," which appeared in the July 1965 Review, describes some of his work.

Dr. Hermann W. Ehrenspeck is a physicist in the Waves and Circuits Branch, Microwave Physics Laboratory, AFCRL. He has been with AFCRL since 1953, and is currently working on surface wave antennas. In the July 1965 issue of the Review, his work in developing and testing an antenna based on a new principle is described in " 'Short-Backfire' Antenna." Dr. Ehrenspeck received his M. S. in Physics and Engineering in 1937 from the Munich Institute of Technology, Munich, Germany. He won his Ph. D. in 1947. Since coming to AFCRL, he has discovered five new antenna types, in addition to finding a new designing method for Yagi antennas with maximum gain. Dr. Ehrenspeck has a number of publications to his credit.

new instruments for AIRBORNE GEOLOGICAL SURVEYS

CAPTAIN DONALD W. GLICK, Terrestrial Sciences Laboratory, AFCRL

Two new AFCRL airborne sensors--advanced instrumentation for aerial surveys of earth surface features--have recently drawn considerable military and scientific interest.

The first is a nine-lens camera which enables simultaneous photographs to be taken in nine narrow-band regions of the visible and near-infrared spectrum. Each type of surface material reflects solar radiation in a characteristic manner which can be detected and resolved as spectral signatures which correlate closely with their compositional differences. The recording of each spectral band separately on film allows analysis of the tonal contrast of any given earth area or type, and application of color-enhancement techniques emphasizes any outstanding features or anomalies. The camera is currently being evaluated by AFCRL in airborne surveys of lava craters, dry lake beds, and beach areas.

The spectral camera, in addition to its use in airborne surveys of the earth's surface, could prove of great value in surveys of the surface features of the moon. In recognition of this, NASA has requested use of this camera in the Apollo Extended Systems portion of their manned space science program.

In addition to NASA interest, a formal request has been received from the U.S. Military Advisory and Assistance Group, acting for the Italian Air Force, to use this camera in archaeological studies of the Sybaric Plain in Italy, where it may likely reveal distinctive soil patterns related to lost or buried cities of the past. Scheduling problems are being worked out whereby it may be possible to use the camera for this purpose in late 1965.

The second sensor is an advanced infrared scanner. It employs an optical-mechanical imaging system for continuous mapping of radiant temperature distributions which are functions of terrain type, moisture content, vegetative cover, and surface roughness. Such imagery presents a photographic record of infrared energy which is susceptible to analysis similar to standard aerial photo-interpretation. Flight tests have shown that the scanner generates imagery superior to that from any such device now in the military inventory.

ARPA has asked AFCRL for the use of the sensor in a field program to detect and map cultural and military features of significance to limited-war activities in remote areas. The scanner was sent to Thailand where it will be used for a two-month's series of airborne surveys of that region.

These airborne sensors were developed under the direction of Carlton E. Molineux. A C-130 aircraft is currently being instrumented for these and other optical, thermal, photographic, and electromagnetic sensors to be used in airborne surveys of geological features of interest. This program has been under way for several years to permit analysis of geological features over wide and diverse geographic areas of the world. ★

A HIGH-ENERGY MOLECULAR-BEAM ACCELERATOR

DR. AMOS G. HORNEY, Directorate of Chemical Sciences, AFOSR

A new accelerator which may do for chemical research what the cyclotron did for physics is being developed by Dr. Lennard Wharton at the University of Chicago with the support of the Air Force Office of Scientific Research. This device will be capable of firing a whole molecule at an atomic target, and may enable chemists to learn the secrets of molecular collisions, which are the basis of all chemical reactions.

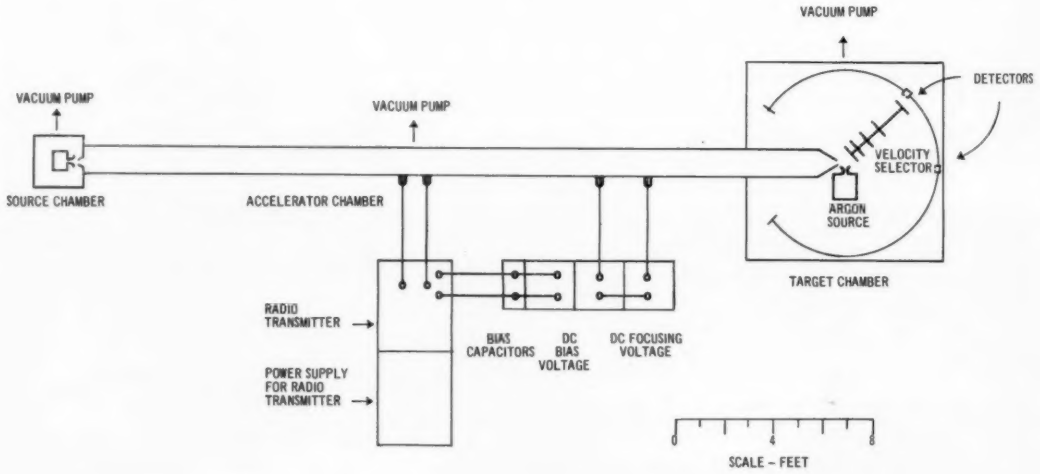
The molecular-beam accelerator will employ many of the principles of giant particle accelerators developed for research in nuclear physics. A thousand acceleration stages within a 30-foot chamber will be used to build up a high-energy beam of gas molecules, all moving at essentially the same speed and in the same direction. An atomic target will be bombarded by this beam, and the resulting molecular collisions will be studied for information on the nature of chemical reactions.

In nuclear physics, an accelerator such as a cyclotron uses electrical fields to speed up subatomic particles. Each particle bears an electrical charge, and these charged particles are accelerated and focused by electrical fields into a high-energy beam that can smash target atoms. Research with such atom-smashers has opened up the vast fields of nuclear physics, subatomic physics, and atomic energy.

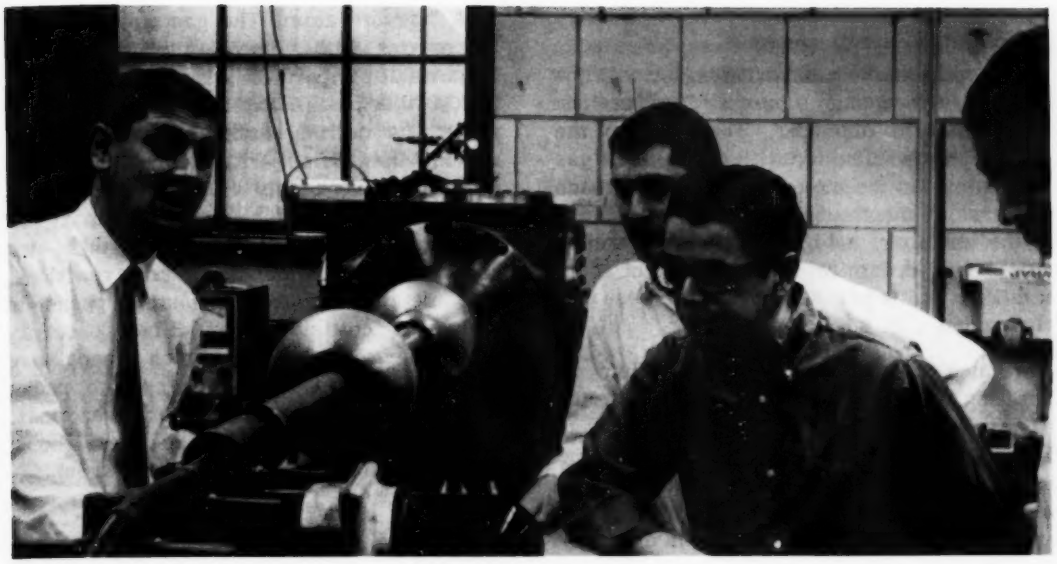
Chemists are interested in studying what happens when gas molecules collide at high speeds. Molecules, which consist of two or more atoms bonded together, do not carry an electrical charge. Molecular beams have been created by introducing a stream of gas into a vacuum chamber. However, no electronic method for both accelerating and focusing molecules into a beam of predetermined velocity has been available.

The main difference in principle between the nuclear accelerator and the molecular accelerator is that nuclear particles are accelerated as electrically charged particles, whereas molecules will be accelerated as uncharged particles.

A molecular-beam accelerator is theoretically possible because even electrically neutral, uncharged particles are affected to some extent by powerful electrical fields.



MOLECULAR ACCELERATOR–EXPERIMENTAL LAYOUT



Experiment of Accelerator for Molecules

LENNARD WHARTON, (left) Assistant Professor of Chemistry, inspects vacuum chamber containing pair of electrodes similar to those which would be used in "molecular-beam accelerator" being designed at The University of Chicago. New type of accelerator would enable scientists to study individual collisions between molecules which are the basis of all chemical reactions. Working with Wharton are (l. to r.) Edward Bromberg, George Ury, and Edward Richman, all graduate students.

Such fields affect molecules with only $\frac{1}{10,000,000}$ of the force they would exert on charged particles.

The molecular collisions that cause chemical reactions are so frequent that chemists have found it difficult to observe such collisions one at a time. A beam of known molecules speeding in a vacuum chamber at a known speed will enable chemists to study what happens in a single molecular collision occurring under specified conditions.

Chemists studying molecular collisions in the past have created molecular beams by allowing two streams of gas to effuse from separate sources into a vacuum chamber. The beams are made to intersect, molecular collisions occur, and some of the colliding molecules are scattered away from this point of intersection. This technique currently has two major limitations:

(1) The beams contain molecules with widely different velocities. The resulting data are inadequate to answer many important chemical questions, such as whether a chemical effect is caused by many collisions between slow-moving molecules, or by a few collisions between fast-moving molecules. A molecular-beam accelerator will create beams in which all the molecules are moving at substantially the same velocity.

(2) The velocity of the molecules studied has been limited to those energies below 3,000 degrees Fahrenheit. Higher velocities are of fundamental chemical interest.

Temperature ranges from minus 260 degrees Fahrenheit to plus 2,000 degrees Fahrenheit are associated with energies ranging from 0.01 electron volts to 0.1 electron volts. The new molecular-beam accelerator will produce beams of molecules with energies of 0.1 to 4 electron volts, with a very narrow distribution of velocities. This will permit the first direct and detailed

study of the collisional properties of molecules in this energy range.

The molecular-beam accelerator will occupy a high-vacuum chamber 30 feet long and 1 foot in diameter. The inlet to the accelerator will be fed with a stream of gas molecules. As the molecules of gas approach the first of the thousand pairs of electrodes in the chamber, a high-power radio transmitter will create an electric field of about a million volts per centimeter between the electrodes.

A fundamental engineering problem in creating this accelerator is to keep the beam focused. The acceleration process has an intrinsically divergent effect on the beam. However, the beam can be confined with electrostatic lenses whose focal properties are similar to those used in alternating gradient particle accelerators. The art is in spacing these lenses correctly.

In a typical experiment, the molecular-beam accelerator which Dr. Wharton is designing will fire a simple, 2-atom molecule at a "target" atom. The gas molecules will be moving with velocities typically found in gases at temperatures ranging from 9,000 to 80,000 degrees Fahrenheit.

When a collision takes place, the fast-moving molecules will spin and vibrate internally. Extremely violent collisions will cause the molecules to break apart, or "dissociate." Collisions of this kind contribute to chemical dissociation reactions.

A detailed study of what happens in molecular collisions should help chemists determine the paths by which dissociative chemical reactions take place, and to predict the rates of unmeasured chemical reactions. The results will also aid in the understanding of what is called the "three-body recombination" reaction. This is the reverse process to dissociation.

The accelerator should also be useful in studying gas-gas, gas-liquid, and gas-solid accommodation processes which are significant in the understanding of atmospheric phenomena, air-foil behavior, shock fronts, and heterogeneous phase chemical reactions.

On an Atmospheric Doppler Shift and its Relation to the Gravitational Frequency Shift

DR. BRUNO J. MANZ, Mathematics Division, ORA

Frequency shifts between an emitter and receiver of light can be generated in several ways. The most familiar frequency shift is generated by a relative velocity between emitter and receiver. In this paper, we are concerned with frequency shifts which do not stem from a relative velocity between emitter and receiver. To eliminate this relative velocity, we imagine that both, emitter and receiver, are mounted on a rigid body. This leaves, it seems, three ways of generating a frequency shift:

1. By subjecting the rigid body to a gravitational field.

2. By subjecting it to acceleration.

3. By making the travel time for light between emitter and receiver a function of time such that consecutive crests of electromagnetic oscillation need different travel times.

The third generation can be achieved by mounting emitter and receiver on a rigid, slender bar that moves in the direction of its length axes along a radial line through the earth's atmosphere.

To the three ways of generation correspond the "gravitational," "accelerational," and "atmospheric" frequency shifts. Whereas the first two are purely relativistic in nature, the third is truly classic.

If we confine consideration to first-order effects, the total frequency shift is a superposition of the three single shifts:

$$\frac{\Delta \omega}{\omega} = \left\{ \lambda + \frac{a}{g} - 1 \right\} \frac{\Delta \varphi}{c^2}$$

where ω is the frequency, g the terrestrial gravitational acceleration, a the downward acceleration of the bar, $\Delta\varphi$ the difference of gravitational potential between emitter and receiver, and c the vacuum speed of light. The constant λ obeys the relation

$$\lambda = \gamma(n-1)\frac{vc}{u^2}$$

where γ is the ratio of specific heats for air, n the refractive index for air, u the speed of sound in air, and v the downward velocity of the bar. The terms with λ, $\frac{a}{g}$ and -1 describe the atmospheric, accelerational and gravitational effects. The effects are capable of compensating each other. For example, the accelerational and gravitational effects compensate for a = g. If t denotes the time, and if the bar velocity was zero at time zero, we have

$$v(t) = gt$$

and consequently

$$\frac{\Delta\omega}{\omega} = \frac{\gamma(n-1)\, g^2\, t\, \Delta R}{u^2 c}$$

where ΔR is the distance between emitter and receiver. This result is remarkable, for it offers the rare opportunity to observe an effect which is quadratic in g. Even more interesting is the compensation between atmospheric and gravitational shifts which obtains for a=o and $\lambda = 1$.

It then follows

$$v = v^* \frac{u^2}{\gamma(n-1)c}$$

where v^* is the "compensation velocity," i.e., that special bar velocity for which the gravitational and the atmospheric frequency shift compensate. If $v > v^*$, the atmospheric is greater than the gravitational frequency shift.

The compensation velocity is surprisingly moderate. To estimate its order of magnitude, let us assume

$$c \approx 3.0 \times 10^8 \text{ m/s}$$

for the vacuum speed of light,

$$u \approx 3.3 \times 10^2 \text{ m/s}$$
$$n-1 \approx 2.9 \times 10^{-4}$$

$$\gamma \approx 1.4 \times 10^0$$

for the speed of sound, the refractive index and the ratio of specific heats of air under normal conditions, and

$$g \approx 9.8 \times 10^0 \text{ m/s}^2$$

for the gravitational field in the vicinity of the surface of the earth. It then follows

$$v^* \approx 9.0 \times 10^{-1} \text{m/s}$$

Hence, you can easily achieve this velocity and thus compensate the atmospheric and gravitational frequency shift. To measure these effects is another matter. A few years ago this was completely impossible because the required accuracy of time or frequency measurements was far beyond the state of the art. However, the Mössbauer effect changed this. It allows time, frequency or energy measurements with a relative accuracy of 10^{-15}. This made it possible to confirm the gravitational frequency shift about half a century after Einstein's prediction.

☆ ☆ ☆ ☆ ☆

New ARL Brochure

A newly prepared brochure describing the research program of the Plasma Physics Research Laboratory of the Aerospace Research Laboratories is now available. Copies may be obtained by writing to: Major R.C. Wingerson, Director, Plasma Physics Research Laboratory, ARL (ARH), Wright-Patterson AFB, Ohio.

☆ ☆ ☆ ☆ ☆

High-Temperature Silica Glass

1st Lt FRANK E. WAGSTAFF and CAPTAIN KENNETH J. RICHARDS
Metallurgy and Ceramics Research Laboratory, ARL

In a previous article in the OAR Research Review (1), the stability and usable service life of vitreous silica (SiO_2) at high temperatures were discussed. It was pointed out that the use of vitreous silica was not limited by its softening at about 1500°C, but rather by a transformation occurring as low as 1200°C which converts the glass into the crystalline phase, cristobalite. When this occurs, the desirable properties of this unique, thermally shock-resistant glass are lost. If, however, the crystallization rate can be reduced, its usable high-temperature life can be extended. One variable believed to affect the rate of crystallization is the degree of oxygen deficiency in the vitreous silica. That is, since the crystalline phase is apparently less tolerant of deviations from stoichiometry than the glass, the transformation to form cristobalite is hindered if the glass is oxygen deficient (SiO_{2-x}). On this basis, a program was initiated to synthesize oxygen-deficient vitreous silica and to study the effect of deviations from stoichiometry on the crystallization behavior under different environmental conditions.

The procedure used to prepare oxygen-deficient vitreous silica was to mix small amounts of silicon powder with high-purity SiO_2 powder, and to fuse this mixture to form a glass. The melting was accomplished by packing the powder in a silica tube connected to a vacuum system and inductively heating the tube to 1850° C using a graphite susceptor. Mixtures were prepared with 0, 70, 100, 200, 400, and 800 parts per million (ppm) silicon additions. The final glass boules were cut to provide samples for the crystallization studies.

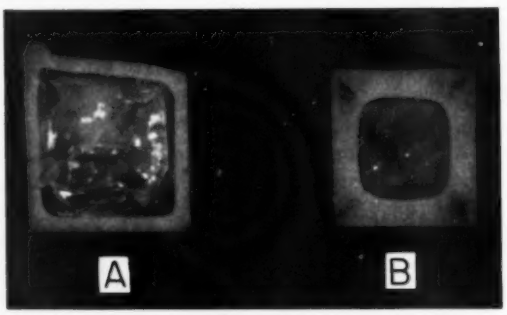


Figure 1 Comparison of crystalline layers formed on vitreous silica heated at 1460°C in water vapor (478 torr). (A) Synthesized oxygen-deficient silica, SiO_{2-x}. (B) Synthesized stoichiometric glass, SiO_2.

A visual comparison of cristobalite layers formed on stoichiometric (0 ppm) and an oxygen-deficient vitreous silica (70 ppm) is shown in Figure 1. Under identical test conditions, the crystallization of the oxygen-deficient glass is much less than for the stoichiometric material. In Figure 2, the growth rates for the two glasses are shown.

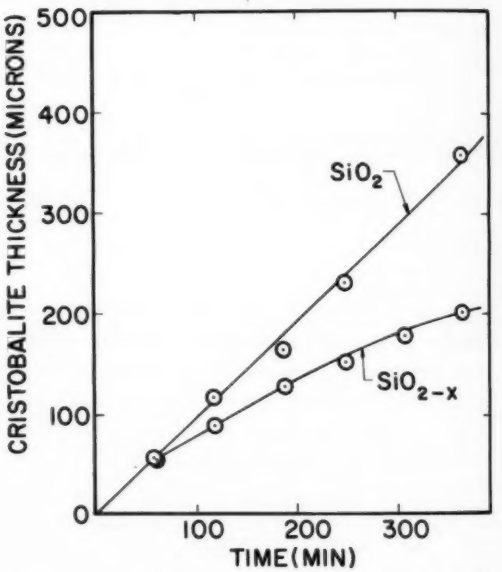


Figure 2 Crystallization of vitreous silica at 1460°C in water vapor (478 torr).

The decreasing growth rate of SiO_{2-x} indicates that crystallization is controlled by diffusion of the oxygen through the growing cristobalite layer. Comparison of the transformation rates for the synthesized glasses showed that the crystallization rates decreased with increasing silicon additions throughout the range studied (0-800 ppm). No

attempt has been made yet to find the limit of this effect.

Another related method of increasing the crystallization resistance of vitreous silica was also found. This involved the incorporation of a second-phase material in the glass that had a large affinity for oxygen. The result is that, before the over-all composition can become stoichiometric with respect to the two resulting stable oxides, large amounts of oxygen must diffuse into the glass. In practice this was accomplished by incorporating 1% boron in a glass matrix. Comparative crystallization of this glass and a commercial silica, General Electric Type 106, is shown in Figure 3. The commercial silica (0.25 inch cube) was completely crystallized, while the cristobalite layer on the synthesized glass with one per cent boron addition was only 0.004 inch thick.

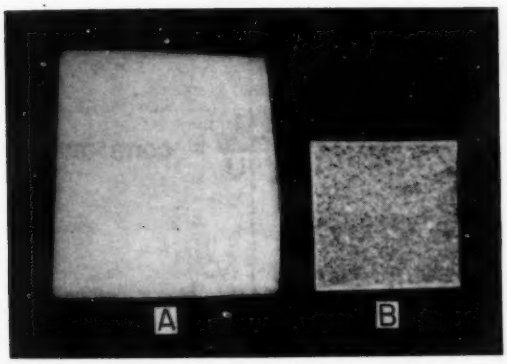


Figure 3 Comparison of degree of crystallization of vitreous silica heated in air for 70 hours at 1450°C. (A) Completely crystallized, commercially fused silica. (B) Slightly transformed synthesized silica containing one percent boron as second phase.

From the results of this investigation, it has been concluded that oxygen deficiency in vitreous silica retards the crystallization and can be used as a means of improving the high-temperature service life of this glass. In conjunction with the Materials Applications Division of the Air Force Materials Laboratory, an effort is now being made to assure the effective application of this material to existing and future aerospace systems' requirements. ★

REFERENCE

(1) Wagstaff, F. E., "New Life for an Old Glass," OAR Research Review, 2, 14, 1963.

Momentum Integral Solutions for Magnetohydrodynamic Boundary Layers*

CAPTAIN RODNEY D. HUGELMAN,
Applied Mathematics Research Laboratory, ARL

Plasma dynamics--the study of the dynamics of ionized fluids--is not new, having long been important in astrophysical problems. In recent years, however, even the engineering frontiers have moved into this realm, and it is no longer the private playground of the astrophysicist. Re-entry of orbiting vehicles, for example, now requires the engineer to consider ionized gas flows. Such vehicles may be winged and operate aerodynamically in a range of flight speeds leading to ionization of the fluid medium. For this reason, considerable research is being done in the area of ionized gas flows.

Just as the study of boundary layers in fluid mechanics has led to a better understanding of flow problems and to the important consideration of boundary-layer control, so the study of the boundary layer in the magnetohydrodynamic (MHD) case might well lead to better understanding and, possibly, boundary-layer control in these new flight regimes.

Two important boundary-layer phenomena are separation and surface friction. Knowledge of both is required if the total drag of the body is to be determined. With such an understanding of the fundamental forces at work in the boundary layer, the possibility of control of these forces can be considered; and, with such control, it may be possible to lower re-entry deceleration forces, reduce heat transfer to the vehicle, prevent instabilities in flight, and even control the vehicle electromagnetically without the necessity for aerodynamic control surfaces of any kind.

One might begin with the incompressible, steady, constant-conductivity, magnetohydrodynamic flow over a two-dimensional body

**A more detailed report has been accepted for publication by the AIAA Journal.*

which will lead to the momentum equation for such a boundary layer (1).

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad (1)$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + m_1 u = -\frac{1}{\rho}\frac{dP}{dx} + \nu\frac{\partial^2 u}{\partial y^2}. \qquad (2)$$

The pressure distribution P is determined by the shape of the body, and m_1, the magnetic field term, is the designer's choice. These equations must now be solved. An exact solution is preferred; but it is not always possible and, in many cases, the designer would be satisfied with an approximate solution.

The author has obtained such solutions to these equations by means of the von Karman-Pohlhausen integral technique (2). In this approach, equation 2 is integrated over the boundary-layer thickness, and an ordinary differential equation is obtained which may be solved much more easily. Often the von Karman-Pohlhausen method fails, however, and it was the author's good fortune to discover one reason for this

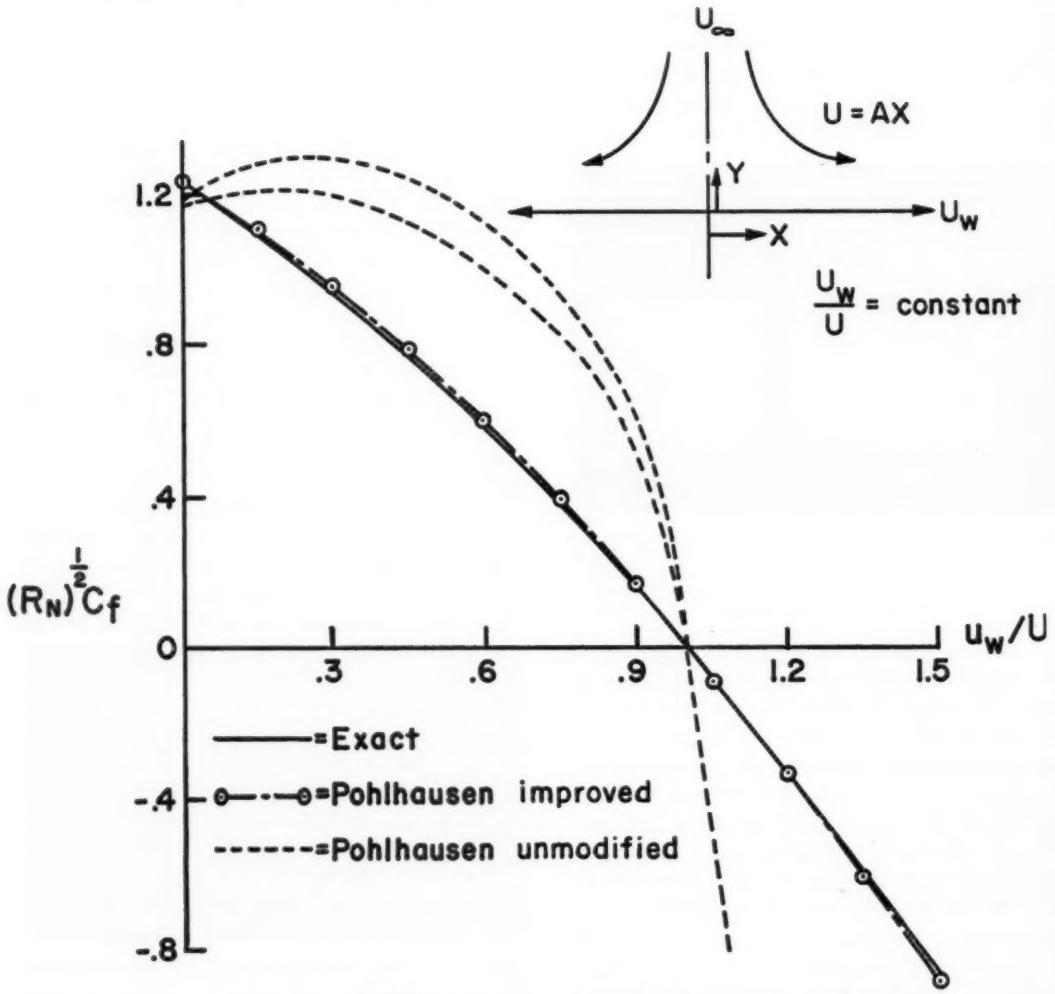


FIG. 1 $(R_N)^{1/2} C_f$ vs u_w/U FOR STAGNATION POINT FLOW

(R_N = Reynolds number, C_f = friction coefficient)

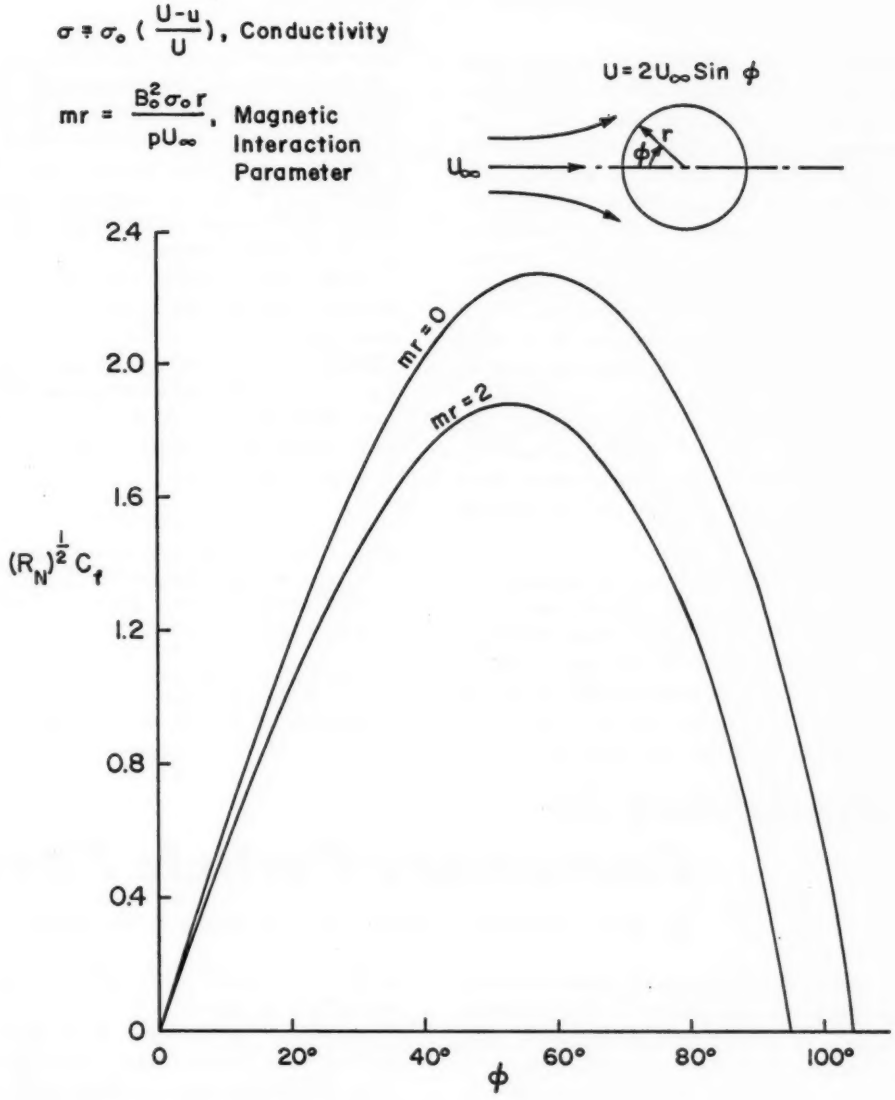


FIG. 2 $(R_N)^{1/2} C_f$ vs ϕ

(R_N = Reynolds number, C_f = friction coefficient)

failure. In this method, the velocity boundary conditions on the surface of the body and at the edge of the boundary layer are satisfied. Also, the derivatives of the velocities are satisfied as boundary conditions at the edge of the boundary layer. These derivatives are ignored at the surface of the body, however; it is this observation which indicates the deficiency in the application of the von Karman-Pohlhausen method. Indeed, since the separation and surface friction are determined by the surface parameters, it is surprising that the method has worked as well as it has in the past.

Figure 1 shows a typical boundary-layer flow case in which the uncorrected von Karman-Pohlhausen method failed. Only at two points does it agree with the known exact solution. Significantly, at these two points, the derivatives at the surface do not

contribute to the solution. For all other values, these derivatives are not trivial and the method fails. Including these derivatives as boundary conditions improves the method and leads to the solution as shown. This improved method has also been applied to the MHD stagnation point, circular cylinder, wedge and flat plate flows with equal success; and in all these instances, the unmodified von Karman-Pohlhausen method fails.

Figure 2 indicates the results of an MHD flow about a circular cylinder for a fluid of variable conductivity (3). It can be seen that a magnetic field will indeed reduce the surface friction on the body. Additionally, Figure 2 shows that the separation point on the cylinder may be changed by varying the magnetic field.

This latter observation is of special interest since it shows that MHD control of a vehicle is, in fact, possible. If the magnetic field were applied only to the upper half of the cylinder, the separation point would be moved forward and the surface drag decreased. As a result, the cylinder would tend to roll counterclockwise, and a force component would be generated, tending to move the cylinder at right angles to the fluid stream. Indeed, the cylinder would be made a lifting body by this means. Since the separation point is rather sensitive, the magnetic fields which would accomplish such a change are well within reason.

While these results are only a small beginning, they are indicative of the new dimensions opened up by MHD. Problems are more difficult, and the vehicle designer's problem may sometimes seem insurmountable; but it may well be that MHD has brought along some solutions with its problems. This only the future will show. ★

REFERENCES

(1) *Pai, Shih-I, Magnetogasdynamics and Plasma Dynamics, Vienna, Springer-Verlag, 1962, pp. 65-67.*

(2) *Schlichting, Herman, Boundary Layer Theory, Fourth Edition, McGraw-Hill, 1960, p. 135.*

(3) *Kantrowitz, A., "A Survey of Physical Phenomena Occurring in Flight at Extreme Speeds," Proceedings of the Conference on High-Speed Aeronautics, Polytechnic Institute of Brooklyn, January 1955, p. 339.*

Symmetries in Elementary-Particle Physics

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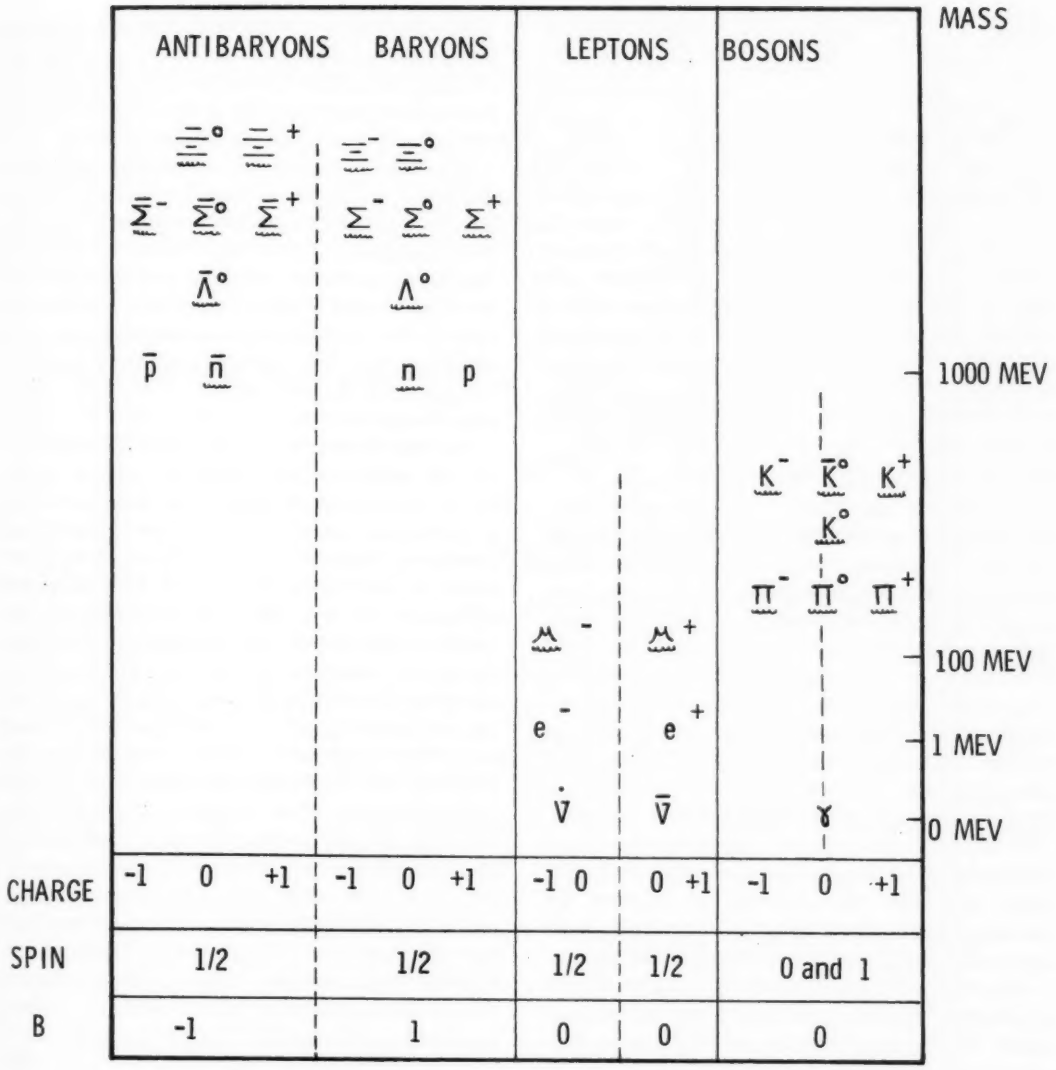
The concept of symmetry in physics stems directly from our everyday notion. By tracing symmetries in a dynamical problem, important conclusions can be reached. For example, a circular orbit of an electron in a hydrogen atom is a consequence and an indication of the symmetry of the Coulomb force exerted by the nucleus on the electron. The symmetry in this case shows that the force has the same magnitude in all directions. Symmetry principles like this have played an important role in classical physics. We are familiar with the set of classical conservation laws: the conservation of energy and the conservation of linear momentum. These follow from the invariance under translations in time and space. The conservation of angular momentum is a consequence of invariance under rotations in space. These laws then result from the homogeneity or symmetry of space.

Symmetry principles also play an important role in elementary-particle physics. With the proliferation of elementary particles in recent years (from 4 to 70!), it has become necessary to classify them in some way, if only to remember them. The classification scheme proposed by Gell-Mann and Ne'eman is based on the symmetries exhibited in elementary-particle interactions. The following is a discussion of some of the symmetry principles deduced from the study of the elementary particles in the last 10 years.

We should first discuss the classification of the strengths of the elementary-particle interactions. It has been observed experimentally that strange particles are produced quite copiously in collisions between high-



(Mass labeling schematic, not to scale.) Unstable particles are identified by wavy lines. B represents baryon number.

energy particles. Since the size of these particles is of the order of 10^{-23} centimeters, and since the velocity of approach between the particles is of the order of 3×10^{10} centimeters per second, the collision time is obviously of the order of 10^{-13} seconds. On the other hand, measurements of the mean lifetime of these unstable particles have shown that these particles live on the average 10^{-10} seconds. Thus, the strange particles are produced in times of the order of 10^{-23} seconds, and disintegrate in about 10^{-10} seconds. In other words, the production process clearly involves forces stronger than the disintegration process by a factor of 10^{13}. This discrepancy has led to the classification scheme illustrated in the following table:

	Strength
1.) Strong Interactions (Nuclear)	1
2.) Electromagnetic Interactions	10^{-2}
3.) Weak Interactions (Decay)	10^{-13}
4.) Gravitational Interactions	10^{-38}

In this table, the strong interactions include those responsible for the production of strange particles, and those representing the forces that bind the particles in the nucleus together. The weak interactions are those responsible for the decays of the unstable elementary particles. In the following paragraphs, we will be concerned with the symmetries of the strong interactions.

One of the phenomena exhibited by strong interaction is called isotopic spin symmetry. Without explaining in detail what this symmetry means, let us examine the figure listing some of the elementary particles. One observes that the particles occur very remarkably in "multiplets" or groups with different charges but almost the identical mass. The oldest known of these multiplets is the one consisting of the neutron and proton. That the neutron and proton are similar to each other, except for their electric charge, has already suggested itself in the phenomenon that nuclei tend to have equal numbers of neutrons and protons. It has also been observed that the newly discovered particles occurred in multiplets.

Closely connected with the isotopic spin symmetry is the rule called the "strangeness conserving rule." Gell-Mann and Nishijima observed that the center of charge of a multiplet of strange particles may be displaced from that of the nonstrange particles: for example the Λ is displaced by a half a unit of charge toward the left from the neutron-proton multiplet. A new quantity called "strangeness" was introduced, with a value equal to twice the amount of this displacement. It can be shown that the isotopic spin symmetry implies that, in a strong interaction, the sum total of the strangenesses of the particles remains unchanged in the process. This rule has become one of the most useful concepts in the study of the strange particles.

In addition to the isotopic spin and strangeness symmetries, the conservation of parity, time-reversal invariance, and charge conjugation invariance play a significant role in the description of elementary particles.

Conservation of parity means that the interactions are the same whether we use a right-handed or a left-handed coordinate system; time-reversal invariance means that the interactions do not depend on the direction of time; and charge conjugation invariance means that the interactions are the same when all particles are changed to antiparticles. Strong interactions appear to satisfy these symmetry conditions.

By identifying some of these symmetries as the operators of a special group, Gell-Mann and Ne'eman have been able to deduce a particular unified system of symmetries and a particular pattern of violations of these symmetries that make plausible the existence of the observed multiplets. The correctness of the classification scheme was strikingly established by the discovery of the Ω particle at approximately the same mass as predicted by the symmetry model. However, the symmetry game may not yet be finished for strongly interacting particles. For example, there might exist some undiscovered quantum number that is conserved by the strong interactions and has value zero for all known particles. Before strange particles were discovered, the strangeness quantum number was of this kind. Experiments at very high energies with the next generation of accelerators might produce a similar situation with respect to an entirely new quantum number. ★

NUMERICAL TREATMENT OF BOUNDARY-VALUE PROBLEMS

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The partial differential equations of mathematical physics give rise to ordinary differential equations in diverse ways. For example, one can view the Dirichlet problem, given a "reasonable" boundary, as an infinite

system of ordinary differential equations satisfying boundary conditions at two distinct values of the independent variable. Such a system is linear and, when properly truncated to a finite system of first-order ordinary differential equations, becomes a linear two-point boundary-value problem for ordinary differential equations, inheriting the properties of existence and uniqueness of solution from its parent problem. The notation and terminology of linear algebra are convenient here. Our problem has the form

$$dy/dx - A(x)y = r(x),\ By(0) = a,\ Cy(1) = b$$

where y, the dependent variable, is an n-vector as is r(x). A(x) denotes an n-square matrix whose entries are functions of x, while B and C denote constant matrices of dimensions n_1 by n and n_2 by n, respectively. The vectors a and b are constant having n_1 and n_2 components, respectively, with $n_1 + n_2 = n$ and $n_1 \geq n_2$.

The numerical analyst encountering such a problem is naturally anxious to apply one of his many effective schemes for solving the initial value problem, to which our problem reduces if $n_2 = 0$. Indeed, the theory of linear differential equations tempts him to do so. He knows that the solution can, in theory, be constructed from the solutions of $n_2 + 1$ initial value problems. One solution, say $y_1(x)$, satisfying the given differential equation and the boundary condition $By_1(0) = a$, can be found together with n_2 linearly independent solutions $\eta_i(x)$, $i = 1, \ldots, n_2$, of the homogeneous differential equation satisfying the boundary conditon $B\eta_i(0) = 0$. This is not a difficult task for fast computers, even if n and n_2 are large. The solution y(x) then has the form

$$y(x) = y_1(x) + \sum_{i=1}^{n_2} c_i \eta_i(x)$$

where the constant c_1 can be determined by imposing the boundary condition $Cy(1) = b$ and solving the resulting n_2-square linear algebraic system. Again, this is a fairly routine computational problem, although not without its pitfalls.

The theory also warns him that such a method cannot in general be successful. Consider a particularly simple special case, one in which the matrix A(x) is constant, positive definite, and with distinct eigenvalues λ_i. Then the solutions of the homogeneous equation are all of the form $\nu_i(x) = d_i \exp(\lambda_i x)$, $i = 1, 2, \ldots, n$. For even moderate values of λ_i, the directions of these vectors will be very difficult to distinguish numerically for $x > 0$, since their components increase at such a rapid rate. Hence, any solution constructed from a linear combination of such vectors, such as that outlined above, may be highly inaccurate. He must, therefore, seek methods which do not involve numerical solutions of the homogenous equation.

The so-called variation of parameters is a possible alternative method of solution; but the solutions of the homogeneous differential equation are necessary for its application also. What is required is a procedure which does not involve numerical solution of the homogenous equation at all. The homogenous solutions $\eta_i(x)$, $i = 1, 2, \ldots, n_2$, form for each value of x a basis for an n_2-dimensional subspace of the space spanned by the n solutions of the homogeneous equation. It would seem to be desirable to confine numerical integrations to a subspace complementary to this n_2-dimensional subspace.

This observation provided the motivation for a report recently completed by Dr. Karl Guderley of the Applied Mathematics Research Laboratory, ARL, and the author, and submitted to a technical journal. (1) There the problem is discussed in full generality, and methods of solution are presented. Concurrently, a comprehensive computer program has been prepared in FORTRAN IV language to test the techniques developed in the report, and to provide practical means for solving two-point problems as they arise in future work at the Laboratory. The methods are currently being applied to boundary-value problems arising in the study of probes in plasmas, and to the study of strains in a notched elastic bar under torsion. ★

REFERENCE

(1) Guderley, Karl G. and Paul J. Nikolai, Reduction of 2-Point Boundary-Value Problems to Initial Value Problems by a Projection in Function Space; submitted for publication.

LATERAL INSTABILITY BY PARAMETRIC EXCITATION

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A major advance in stability and control analysis of flight vehicles was achieved under a research program at the University of Toronto, directed by Professor Bernard Etkin and supported by the Applied Mathematics Division, AFOSR. These results, which represent, mathematically, the effect of longitudinal excitation on lateral stability, were reported in UTIAS Technical Note No. 86, On the Lateral Instabilities of Aircraft Due to Parametric Excitation, by M. Masak, January 1965.

For the purpose of stability and control analysis, the equations of motion of a flight vehicle are frequently written in a linearized form with small perturbations from a steady-flight condition playing the role of the primary variables. Generally, the associated parameters are considered constant coefficients. However, it is shown that, under certain conditions, the stability properties obtained under these assumptions lead to erroneous results, and actually gross instabilities may unexpectedly arise.

In the study, the following situation was considered: an aircraft flying through turbulence is continuously excited by random inputs, about all three axes, containing spectral components that span a wide range of frequencies. As a consequence, all the lateral and longitudinal modes of motion will be excited, and a reference motion must be chosen for the linearization procedure. In the past, it has been assumed that a mean constant value of the lift coefficient, C_L, should be taken as

$$C_L = C_{L_c} \quad (1 + f(t))$$

where C_{L_c} is the mean value of C_L and f(t) is a function of time representing the longitudinal oscillation. For a single spectral component, f(t) can be represented as

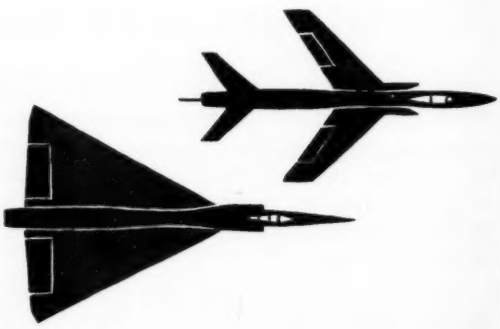
$$f(t) = \epsilon \ \mathrm{Cos}\,\Omega t \quad \text{where } \epsilon < 1 \text{ and}$$

Ω is some constant frequency.

Lateral stability was investigated in the cases of subsonic jet transport and slender supersonic delta transport models. The results indicated that, under sufficiently large parameter oscillations, the lateral dynamics became unstable, although a constant coefficient analysis at these parameter magnitudes indicated stability. Furthermore, the instabilities were most severe where the parameter was oscillating at the frequency of the Dutch roll oscillation, or at twice this frequency. These mathematical predictions were confirmed by programming some typical aircraft on an analog computer and studying their transient oscillations. Also noteworthy was the fact that, even under conditions of stable transients, the natural frequency and damping of some of these transients were significantly altered by the oscillating parameters.

In summary, the fact is that, in relation to swept- and delta-wing aircraft, unstable lateral motions can result from parametric oscillation caused by steady pitching motion. Further research is under way to extend the theory to flight in turbulent air.

The implications of this theory with respect to Air Force technology are being assessed independently. Preliminary findings are as follows: although this phenomenon has been observed, it has not been formulated in a mathematical representation previously; research results should yield design guidelines to insure greater lateral stability and control of swept- and delta-wing aircraft. ★



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